Obtaining the Nuclear Gluon Distribution From Heavy Quark Decays to Lepton Pairs in pA Collisions*

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Inclusive differential cross sections of hard scatterings in proton-nucleus collisions at high energies are, to first approximation, computable assuming factorization so that

$$\sigma_{pA} = \sum_{i,j=q,\overline{q},g} f_i^p(x_1,Q^2) A f_j^A(x_2,Q^2) \hat{\sigma}_{ij} \qquad (1)$$

where $\hat{\sigma}_{ij}$ are the perturbatively calculable partonic cross sections for producing parton a at scale $Q^2 \gg \Lambda^2_{\rm QCD}$, x_1 and x_2 are the momentum fractions of the partons involved in the hard scattering, while $f_i^{\rm p}$ and f_i^A are the distributions of parton i in a free proton and a nucleus of mass A. In the high-Q^2 limit, the parton distributions will be modified in the nucleus [1]. Equation (1) may be generalized to nucleus-nucleus collisions.

The scale evolution of the nuclear parton distributions is, to a first approximation, similar to that of the free proton. There remain uncertainties, especially in the determination of the nuclear gluon distributions. So far there are no direct constraints on the nuclear gluon distributions, only indirect ones. More measurement-based constraints are thus vital. Heavy quark production is one such process.

The dominant subprocess of heavy quark production in hadronic or nuclear collisions is $gg \to Q\overline{Q}$. The produced heavy quarks fragment into mesons which may decay semi-leptonically. Lepton pairs formed from these decay leptons thus carry direct information about the input nuclear gluon distribution.

We calculate lepton pair production from heavy quark decays in pA and pp collisions using the EKS98 [1] nuclear modifications to the parton distributions. We show that the resulting cross section ratios of pA to pp rates reflect the initial nuclear modifications of gluons rather well. Based on these results, we conclude that if the ratio of leptonic cross sections were measured within an acceptable accuracy, the nuclear gluon distributions could be determined. Several such measurements have been proposed.

The NA60 experiment at the SPS plans to measure charm production through lepton decays. At this energy, a 20% antishadowing manifests itself as a 10% enhancement. With sufficient accuracy, NA60 results could be used to pinpoint the behaviour of nuclear gluon distribution in the range $0.17 < x < 0.4$.

At RHIC, the PHENIX detector will use lepton pairs to measure heavy quark production at x values as low as 3×10^{-3}. In this x region, the Q^2 dependence of gluon modifications should be larger than at the SPS. The nuclear effects vary from 20% shadowing for charm to slight antishadowing for bottom.

The ALICE detector is designed to study nucleus-nucleus interactions at the LHC. The high LHC energy makes it ideal for probing nuclear effects of gluon distributions and studying saturation effects at low x. For x values as low as 3×10^{-5}, the evolution in Q^2 should be measurable. Here, the nuclear modifications are an $\sim 30\%$ effect.

Together, all three experiments provide a large lever arm in $\langle x_2 \rangle$ and $\langle Q^2 \rangle$ over which to study the nuclear gluon distribution. Measurements at the same energy in pA and pp interactions should reveal much new information on the nuclear gluon distribution, providing valuable input to AA interactions.

[1] K.J. Eskola, V.J. Kolhinen and C.A. Salgado, Eur. Phys. J. **C9** (1999) 61.

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